JC07 Rec'd PCT/PTO 05 FEB 2002

FORM PTO-1390 (REV. 5-93)	U.S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 10901/36
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U.S APPLICATION NO (If known, see 37 CFR 1 5) 10/069086

INTERNATIONAL APPLICATION NO. PCT/EP00/06772	INTERNATIONAL FILING DATE 15 July 2000 (15.07 00)	PRIORITY DATE CLAIMED 01 August 1999 (01 08.99)

TITLE OF INVENTION
REFLECTOMETER AND METHOD FOR MANUFACTURING A REFLECTOMETER

APPLICANT(S) FOR DO/EO/US
WEIDMANN, Josef, and SPECKBACHER, Peter

Applicant(s) herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1)
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date
5. ☒ A copy of the International Application as filed (35 U S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C 371(c)(2))
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C 371(c)(4)). (unsigned)
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1 97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3 28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
    ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☒ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report, and International Examination Report.

EXPRESS NO. EM180521102US

JC13 Rec'd PCT/PTO 05 FEB 2002

U.S. APPLICATION NO if known, see 37 C.F.R.1.5 10/069086	INTERNATIONAL APPLICATION NO PCT/EP00/06772	ATTORNEY'S DOCKET NUMBER 10901/36

17. ☐ The following fees are submitted:

Basic National Fee (37 CFR 1.492(a)(1)-(5)):
Search Report has been prepared by the EPO or JPO $890.00

International preliminary examination fee paid to USPTO (37 CFR 1 482) ... $710 00

No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) $740.00

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO $1,040.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100.00

				CALCULATIONS	PTO USE ONLY
ENTER APPROPRIATE BASIC FEE AMOUNT =				$890 00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
Claims	Number Filed	Number Extra	Rate		
Total Claims	18 - 20 =	0	X $18.00	$	
Independent Claims	1 - 3 =	0	X $84.00	$	
Multiple dependent claim(s) (if applicable)			+ $280.00	$	
TOTAL OF ABOVE CALCULATIONS =				$890.00	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1 9, 1 27, 1.28).				$	
SUBTOTAL =				$890.00	
Processing fee of $130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)) +				$	
TOTAL NATIONAL FEE =				$890 00	
Fee for recording the enclosed assignment (37 CFR 1 21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$	
TOTAL FEES ENCLOSED =				$890.00	
				Amount to be: refunded	$
				charged	$

a. ☐ A check in the amount of $________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of **$890.00** to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600 A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Kenyon & Kenyon
One Broadway
New York, New York 10004

26646
PATENT TRADEMARK OFFICE

444795

SIGNATURE

Reg. No. 46,739 For:

Richard L. Mayer
NAME

22,490
REGISTRATION NUMBER

2/5/02
DATE

1006908610/069086
Rec'd PCT/PTO 08 JUL 2002
[10901/36]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s)	:	Josef WEIDMANN et al.
Serial No.	:	10/069,086
Filed	:	February 5, 2002
For	:	REFLECTOMETER AND METHOD FOR MANUFACTURING A REFLECTOMETER
Examiner	:	To Be Assigned
Art Unit	:	To Be Assigned

Assistant Commissioner
for Patents
Washington, D.C. 20231

SECOND PRELIMINARY AMENDMENT

SIR:

Kindly amend the above-captioned application before examination, as set forth below.

IN THE CLAIMS:

Please cancel claims 20 to 38 without prejudice.

Please add the following new claims:

--39. (New) A reflection graduation, comprising:

a silicon substrate;

first subsections disposed on the substrate, each of the first subsections having etched oblique surfaces, the surfaces positioned such that light beams directed incident to the surfaces cause no retroreflection; and

second subsections having relatively higher reflecting properties as compared to the first subsections;

wherein the first subsections and the second subsections are alternatively disposed on the substrate in a first direction.

40. (New) The reflection graduation as recited in claim 39, wherein the oblique surfaces include a plurality of adjacent V-shaped grooves disposed in a

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second direction perpendicular to the first direction, each groove including a first surface and a second surface.

41. (New) The reflection graduation as recited in claim 40, wherein the grooves are regularly spaced in the first subsections.

42. (New) The reflection graduation as recited in claim 40, wherein the first surface and the second surface of each groove are oriented at an angle of approximately 72° to one another.

43. (New) The reflection graduation as recited in claim 39, wherein the silicon substrate includes monocrystalline silicon, and wherein the first direction corresponds to a direction of the monocrystalline silicon.

44. (New) The reflection graduation as recited in claim 39, wherein a width in the first direction of each first subsection is equivalent to a width in the first direction of each second subsection.

45. (New) The reflection graduation as recited in claim 40, wherein each first subsection includes at least one secondary V-shaped groove that extends in the second direction along nearly an entire length of an edge of each first subsection.

46. (New) The reflection graduation as recited in claim 39, wherein the second subsections include a coating of highly reflective material.

47. (New) The reflection graduation as recited in claim 39, wherein the oblique surfaces form pyramid-shaped depressions.

48. (New) The reflection graduation as recited in claim 39, wherein the oblique surfaces are positioned so that a light beam directed thereon from a direction of incidence reflects from the oblique surfaces in a direction that coincides with a direction other than the direction of incidence.

49. (New) A method for manufacturing a reflection graduation, comprising the steps of:

providing a silicon substrate; and

forming first subsections and second subsections that alternatively extend in a first direction on the silicon substrate, the first subsections and the second subsections having different optical reflecting properties;

wherein, in the first subsections, a plurality of oblique surfaces is produced by deep etching, the oblique surfaces positioned such that no retroreflection of the light beams incident thereto results.

50. (New) The method as recited in claim 49, further comprising the step of forming a plurality of V-shaped grooves in a second direction perpendicular to the first direction.

51. (New) The method as recited in claim 50, wherein the forming step includes the substep of selectively etching oblique surfaces into the silicon substrate using an etching solution in a region of the first subsections.

52. (New) The method as recited in claim 51, further comprising the step of covering at least the second subsections with an etching mask on the silicon surface prior to the forming step.

53. (New) The method as recited in claim 52, wherein the etching mask includes chromium.

54. (New) The method as recited in claim 51, wherein the etching solution includes potassium hydroxide in combination with isopropanol.

55. (New) The method as recited in claim 51, wherein the etching step continues until each of the V-shaped grooves is completely formed.

56. (New) The method as recited in claim 52, further comprising the step of removing the etching mask after completion of the forming step.

57. (New) The method as recited in claim 49, further comprising the step of etching a plurality of pyramid-shaped depressions into the silicon substrate in the first subsections.--.

REMARKS

With the cancellation herein, without prejudice, of claims 20 to 38, and the addition of new claims 39 to 57, claims 39 to 57 are pending in the present application.

Applicants assert that the subject matter of the present application is new, non-obvious and useful. Prompt consideration and allowance of the application is respectfully requested.

Respectfully submitted,

KENYON & KENYON

Richard L. Mayer

Dated: 7/8/02

By: Mary C. Werner Reg No. 30,333

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PATENT TRADEMARK OFFICE

10/069086
JC13 Rec'd PCT/PTO 05 FEB 2002

[10901/36]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventors	:	WEIDMANN et al.
Serial No.	:	To Be Assigned
Filed	:	Herewith
For	:	REFLECTION MATERIAL MEASURE AND METHOD FOR PRODUCING A REFLECTION MATERIAL MEASURE
Examiner	:	To Be Assigned
Art Unit	:	To Be Assigned

Assistant Commissioner
for Patents
Washington, D.C. 20231
Box Patent Application

PRELIMINARY AMENDMENT AND
37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT

SIR:

Please amend the above-identified application before examination, as set forth below.

IN THE SPECIFICATION AND ABSTRACT:

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract, but without claims) accompanies this response. It is respectfully requested that the Substitute Specification (including Abstract) be entered to replace the Specification of record.

IN THE TITLE:

Please replace the title with the following:
--REFLECTOMETER AND METHOD FOR MANUFACTURING A REFLECTOMETER--.

EM180521102US

IN THE CLAIMS:

On the first page of the claims, first line, change "What is claimed is:" to: --What Is Claimed Is:--.

Please cancel original claims 1 to 18, without prejudice, and cancel substitute claims 1 to19, without prejudice, in the underlying PCT Application No. PCT/EP00/06772.

Please add the following new claims:

20. (New) A reflectometer comprising:

a silicon substrate;

first subsections disposed on the substrate, each of the first subsections having etched oblique surfaces, the surfaces positioned to that light beams directed incident to the surfaces cause no retroreflection; and

Second subsections having relatively higher reflecting properties as compared to the first subsections;

wherein first subsections and second subsections are alternatively disposed on the substrate in a first direction.

21. (New) The reflectometer as recited in claim 1, wherein the oblique surfaces comprise a plurality of adjacent V-shaped grooves, the grooves disposed in a second direction perpendicular to the first direction, each of the grooves having a first surface and a second surface.

22. (New) The reflectometer as recited in claim 2, wherein the grooves are regularly spaced in the first subsections.

23. (New) The reflectometer as recited in claim 2, wherein the first surface and the second surface of each of the grooves are oriented at an angle of approximately 72° to one another.

24. (New) The reflectometer as recited in claim 1, wherein the silicon substrate

is monocrystalline silicon, and wherein the first direction corresponds to a direction of the monocrystalline silicon.

25. (New) The reflectometer as recited in claim 1, wherein a width in the first direction of each of the first subsections is equivalent to a width in the first direction of each of the second subsections.

26. (New) The reflectometer as recited in claim 2, wherein each of the first subsections further comprises at least one secondary V-shaped groove that extends in the second direction along nearly an entire length of an edge of each of the first subsections.

27. (New) The reflectometer as recited in claim 1, wherein a coating of highly reflective material is applied to the second subsections.

28. (New) The reflectometer as recited in claim 1, wherein the oblique surfaces form pyramid-shaped depressions.

29. (New) The reflectometer as recited in claim 1, wherein the oblique surfaces are positioned so that a light beams directed thereon from a direction of incidence will reflect from the oblique surfaces in a direction that coincides with a direction other than the direction of incidence.

30. (New) A method for manufacturing a reflectometer comprising the steps of:

providing a silicon substrate;

forming first subsections and second subsections that alternatively extend in a first direction on the silicon substrate, the first subsections and the second subsections having different optical reflecting properties;

wherein, in the first subsections, a plurality of oblique surfaces is produced by deep etching, the oblique surfaces positioned such that no retroreflection of the light beams incident thereto results.

31. (New) The method as recited in claim 11 further comprising the step of:

forming a plurality of V-shaped grooves in a second direction perpendicular to the first direction.

32. (New) The method as recited in claim 12, wherein the forming step includes selectively etching oblique surfaces into the silicon substrate using an etching solution, in a region of the first subsections.

33. (New) The method as recited in claim 13 further comprising a step, prior to the forming step, of:

covering at least the second subsections with an etching mask on the silicon surface.

34. (New) The method as recited in claim 14, wherein the etching mask is formed from chromium.

35. (New) The method as recited in claim 13, wherein the etching solution is formed from potassium hydroxide in combination with isopropanol.

36. (New) The method as recited in claim 13, wherein the etching process continues unitl each of the V-shaped grooves is completely formed.

37. (New) The method as recited in claim 14, further comprising the step of:

removing the etching mask after completion of the forming step.

38. (New) The method as recited in claim 11, wherein a plurality of pyramid-shaped depressions is etched into the silicon substrate in the first subsections.

Remarks

This Preliminary Amendment cancels original claims 1-18, without prejudice, and also cancels substitute claims 1 to 19, without prejudice, in the underlying

PCT Application No. PCT/EP00/06772. The Preliminary Amendment also adds new claims 20-38. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/EP00/06772 includes an International Search Report, dated December 18, 2000, and an International Preliminary Examination Report, dated November 20, 2001, copies of which are submitted herewith.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

KENYON & KENYON

Dated: 2/5/02

By: [signature] Reg. No. 46,739 For:

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10/069086
JC13 Rec'd PCT/PTO 05 FEB 2002

[10901/36]

REFLECTION-TYPE GRADUATION AND METHOD FOR MANUFACTURING A REFLECTION-TYPE GRADUATION

Field of the Invention

The present invention is directed to a reflection-type graduation, as well as to a method for manufacturing a reflection-type graduation.

Related Technology

Reflected-light position encoders usually include a reflection-type graduation, as well as a scanning device that is movable relative to the reflection-type graduation. A light source is typically mounted at the scanning device that emits a light beam in the direction of the reflection-type graduation. From the reflection-type graduation, the light packet is reflected back toward the scanning device, where it is modulated—dependent upon displacement—to pass through one or more graduated-scale scanning structures, and is ultimately measured by a sensing array. The signals generated in this manner, and modulated in dependence upon displacement, are then further processed by a downstream evaluation unit.

Reflection-type graduations are typically made of a substrate material, upon which subsections having different optical properties are placed in alternating sequence. In the case of an incremental graduation, the array of the various subsections extends in the direction of measurement. It can be provided, for example, to produce subsections of high and low reflectivity on a glass substrate. As a substrate material, steel is also used, on which subsections having high and low reflectivity are formed. In this connection, the subsections of high reflectivity can be made of gold. The steel surface is etched to have a frosted texture for the subsections of lower reflectivity, so that the incident light is absorbed or reflected diffusely.

A number of requirements are placed on material measuring standards of this kind. These include a greatest possible abrasion resistance, a high thermal resistance, defined thermal properties, as well as good long-term stability. However, the above-mentioned, known material measuring standards on glass and steel substrates only partially meet these requirements.

Summary of the Invention

An object of the present invention is to devise a reflection-type graduation, as well as a method for manufacturing the same, having the greatest possible abrasion resistance, a relatively high thermal resistance, defined thermal properties, as well as relatively high long-term stability.

This objective is achieved by a reflection-type graduation having a silicon substrate. The silicon substrate has first subsections formed thereon. Each of the first subsections has etched oblique surfaces. The surfaces are positioned so that light beams directed incident to the surfaces cause no retroreflection. The substrate also includes second subsections having relatively higher reflecting properties as compared to the first subsections. The first subsections and second subsections are alternatively disposed on the substrate in a first direction.

The objective at hand is also achieved by a method for manufacturing a reflection-type graduation by providing a silicon substrate; forming first subsections and second subsections that extend in a first direction on the silicon substrate, the first subsections and the second subsections having different optical reflecting properties; wherein, in the first subsections, a plurality of oblique surfaces is produced by deep etching, which are positioned such that no retroreflection of the light beams incident thereto results.

As mentioned, it is provided in accordance with the present invention to employ a silicon substrate and to suitably form the subsections having different reflectivity thereon. Preferably, monocrystalline silicon is used. In this connection, the subsections having less reflectivity each include a plurality of oblique surfaces, which are produced by deeply etching the silicon substrate along different crystal directions. The surfaces are positioned such that no retro-reflection of light rays incident thereto results.

In one preferred specific embodiment of the present invention, the oblique surfaces are made up of V-shaped grooves, which extend in a direction perpendicular or parallel to that direction in which the subsections having different reflective properties are configured. As to the highly reflecting subsections, one may use the bare silicon substrate surface or it is also possible to coat these subsections with a suitable material.

As an alternative to V-shaped grooves, the oblique surfaces in the subsections having low reflectivity may also be formed as deeply etched pyramid structures. There are various ways to produce the requisite oblique surfaces having the appropriate optical action. This variant is especially suited for material measuring standards having coarser graduation intervals.

A material measuring standard of this kind has a number of advantages. Cited in this connection are, first of all, the substantial resistance to abrasion, as well as the very high mechanical resistance of the surface of the material measuring standard. In addition, the preferably monocrystalline silicon substrate is structurally stable and no longer changes, i.e., no undesirable diffusion processes result. Furthermore, silicon possesses defined thermal expansion characteristics, which is especially significant for high-precision applications. Particularly beneficial is, for instance, the use of the material measuring standard according to the present invention in the semiconductor industry, since the position-measuring system in question includes a material measuring standard which has the same thermal expansion coefficient as the semiconductor material to be processed. It should also be mentioned that, as a substrate material, silicon is relatively inexpensive in a defined state, i.e., in a stable quality with respect to impurities and surface quality. Also noted in this connection is the relatively high processability of this material.

The reflection-type graduation according to the present invention may be used, of course, in many different position-measuring devices, i.e., in connection with the most widely varying scanning principles. It is, of course, likewise possible to use the reflection-type graduation according to the present invention in linear measuring systems, as well as in rotary measuring systems or two-dimensional measuring systems. In accordance with the present invention, the most widely varying material measuring standards are able to be produced, such as incremental graduations, code graduations, structures for reference marks, and so forth.

Brief Description of the Drawings

Further advantages of the present invention, as well as details pertaining thereto, are derived from the subsequent description of exemplary embodiments on the basis of the following figures:

Figure 1 is a plan view of an exemplary embodiment of the reflection-type graduation according to the present invention;

Figure 2 is an enlarged detail of the reflection-type graduation of Figure 1;

Figures 3a is a sectional view taken along line IIIa—IIIa of Figure 2;

Figure 3b is sectional view taken along line IIIb—IIIb of Figure 2;

Figure 4 is a sectional view of an individual V-shaped groove of the reflection-type graduation shown in Fig. 3a, showing a light beam incident thereto;

Figure 5a is a side view of a silicon substrate prior to processing for forming the reflection-type graduation of Figure 1;

Figure 5b is a top view of a silicon substrate prior to processing for forming the reflection-type graduation of Figure 1;

Figure 5c is a top view of a silicon substrate for forming the reflection-type graduation of Figure 1, with an etching mask applied on the substrate;

Figure 5d is a side view of a silicon substrate for forming the reflection-type graduation of Figure 1, with an etching mask applied on the substrate;

Figure 5e is a side view of a silicon substrate for forming the reflection-type graduation of Figure 1 being etched to form V-shaped grooves shown in Figure 3b;

Figure 5f is a side view of a silicon substrate for forming the reflection-type graduation of Figure 1 having been etched to form V-shaped grooves shown in Figure 3b;

Figure 5g is a plan view of a silicon substrate for forming the reflection-type graduation of Figure 1 having been etched to form V-shaped grooves shown in Figure 3b;

Figure 5h is a side view of a silicon substrate for forming the reflection-type graduation of Figure 1, after the etching mask has been removed from the substrate;

Figure 6 is a scanning electron-microscope image of a part of the reflection-type graduation of the present invention in accordance with the first exemplary embodiment; and

Figure 7 is a scanning electron-microscope image of a part of a reflection-type graduation of the present invention in accordance with a second exemplary embodiment.

Detailed Description

Figure 1 is a plan view of a first exemplary embodiment of the reflection-type graduation in accordance with the present invention that may be employed, for example, in a position-measuring device used for measuring linear displacements between two objects which are movable relatively to one another.

For this exemplary embodiment, reflection-type graduation 1 is essentially composed of an oblong silicon substrate 2 that extends in measuring direction x and on which an incremental graduation track 3 is arranged. Incremental graduation track 3, in turn, is made up of first and second rectangular subsections 4a, 4b, which exhibit different optical reflecting properties for light incident thereto. Reference numeral 4a denotes the subsections of lower reflectivity; reference numeral 4b denotes the subsections of high reflectivity. Subsections 4a, 4b having low and high reflectivity are arranged in alternating sequence in a first direction x, which also corresponds to the measuring direction along which a relative displacement would be measured in a corresponding position-measuring device. Various subsections 4a, 4b are identically constructed with respect to their geometric dimensions. In first direction x, they have a width b; perpendicular thereto, in second direction y, they extend over length l, which, in this example, also corresponds to the width of incremental graduation track 3.

In this specific embodiment, subsections 4b, designed to reflect incident light bundles, are formed on the surface of silicon substrate 2. In this instance, monocrystalline silicon substrate material having crystal orientation 100 is selected. At a wavelength $\lambda = 860$ nm, this material has a reflectance of about 32%, thereby ensuring sufficient quality of the generated sampled signals for a reflection-type graduation.

A detailed description of subsections 4a having low reflectivity in accordance with the present invention is provided with reference to subsequent Figures 2 - 4. Figure 2 illustrates the detail marked in Figure 1 of reflection-type graduation 1, in an enlarged representation. The two Figures 3a and 3b portray sectional views of the cut-away portion in Figure 2 through the indicated lines of intersection IIIa—IIIa and IIIb—IIIb, respectively.

In the first specific embodiment, the present invention provides each of subsections 4a having low reflectivity with a plurality of oblique surfaces formed as V-shaped grooves 5.1 - 5.10, 6.1 - 6.4, which are positioned in a second direction, perpendicular or in parallel to a first direction x. In the illustrated exemplary embodiment, the second direction corresponds to the y-direction. In Figure 3b, a longitudinal section through a subsection 4a along line of intersection IIIb—IIIb is shown, which makes the arrangement of the multiplicity of V-shaped grooves 5.1 - 5.10 discernible.

As is likewise indicated in Figure 2, the (011) direction of silicon substrate 2 coincides with the x-direction; the (0-11) direction of silicon substrate 2 coincides with the y-direction, while the z-direction corresponds to the (100) direction.

A detailed view of single V-shaped groove 5.1 from Figure 3a is shown by Figure 4, once again in an enlarged representation; in particular the optical action of oblique surfaces, i.e., of V-shaped grooves on an incident light beam is shown here.

As is discernible in Figure 4, two surfaces 5.1a, 5.1b form an angle $\alpha \approx 72°$ with one another; angles β_a, β_b of the two lateral surfaces 5.1a, 5.1b formed with plane E amounting accordingly to $\beta_a = \beta_b \approx 54°$. Given such a geometrical dimensional design of V-shaped groove 5.1, a light beam L coming from direction of incidence IN is reflected in the illustrated manner twice off of side surfaces 5.1a, 5.1b and ultimately leaves V-shaped groove 5.1 in reflection direction OUT, which does not coincide with incident direction IN. Viewed from incident direction IN, when working with a multiple reflection of this kind, subsection 4a having a multiplicity of such V-shaped grooves 5.1 - 5.10 and 6.1 - 6.4 is less reflective than neighboring subsections 4b having plane surfaces, since no retroreflection of the light beams incident thereto results.

The oblique surfaces, i.e., V-shaped grooves disposed in accordance with the present invention in the less reflective subsections 4a are able to be manufactured advantageously due to the existing orientations of certain crystal planes of silicon substrate 2. Details pertaining to the method of the present invention are explained in the following description, on the basis of Figures 5a - 5h.

In the illustrated exemplary embodiment of reflection-type graduation 1 according to the present invention in Figures 2, 3a, 3b, not only V-shaped grooves 5.1 - 5.10 are provided in the less reflecting subsections 4a, which extend in adjoining fashion in second direction y that is oriented normally to first direction x. Rather, disposed adjacently to each of longitudinal edges of subsections 4a is at least one further V-shaped groove 6.1 - 6.4, which extends nearly over entire length l of subsections 4a in the y-direction. Reference is especially made, in this connection, to the sectional view in Figure 3a, where the configuration of these additional V-shaped grooves 6.1 - 6.4 is more clearly apparent at the edges of the less

reflecting subsections 4a.

This advantageously ensures that various subsections 4a, 4b are sharply delimited from one another at the additional, lateral V-shaped grooves 6.1 - 6.4. These additional V-shaped grooves 6.1 - 6.4 are not essential, however, to the functioning of reflection-type graduation 1 according to the present invention.

It is also optionally possible for the oblique surfaces to be formed as a multiplicity of pyramids or as pyramid-shaped depressions in subsections 4a. These may be spaced at regular intervals or, however, also randomly distributed. This pyramid structure may be produced, just as the V-shaped grooves discussed above, by deeply etching the silicon substrate, for which, then, suitably modified etching masks are needed. For further details on a specific embodiment of this kind of material measuring standard according to the present invention, reference is additionally made here, for example, to the publication by I. Zubel, Silicon Anisotropic Etching in Alkaline Solutions II, Sensors and Actuators, A 70 (1998), pp. 260 - 268, which is incorporated herein by reference.

One exemplary embodiment of the method according to the present invention for manufacturing a reflection-type graduation is elucidated in the following on the basis of Figures 5a - 5h. Here, a method is described which is suited for manufacturing a reflection-type graduation in accordance with the above described exemplary embodiment and in which the oblique surfaces are formed, accordingly, as V-shaped grooves. Such an embodiment in accordance with the present invention permits, in particular, the implementation of very fine graduation intervals.

With respect to a suitable method for manufacturing the mentioned structure having deeply etched, pyramid-shaped depressions, which are especially suited, in turn, for coarser graduation intervals, reference is again made to the above-mentioned publication.

The starting point for the method described in the following is silicon substrate 2 described in Figures 5a and 5b, in which the (011) direction coincides with the x-direction, and the (0-11) direction with the y-direction. This orientation of silicon substrate 2 ensures that the desired, straight edges are obtained.

In a first method step, silicon substrate 2 is provided with an etching mask 10, which, in this example, is composed of a chromium coating. The two views of Figures 5c and 5d show silicon substrate 2 having an applied etching mask 10. The nearly ladder-shaped etching mask 10 is applied here, on the one hand, in subsections 4b having the desired high reflectivity; on the other hand, etching mask 10 is also applied in the regions of low-reflecting subsections 4a, which are located between the V-shaped grooves to be produced, as well as in laterally bordering regions. In this connection, reference is made, in particular, to Figure 5d, which illustrates the regions of substrate material 2 covered by etching mask 10. Accordingly, merely those regions in which the V-shaped grooves are to be formed remain uncovered by etching mask 10 on silicon substrate 2. Etching mask 10 is applied to the desired regions of silicon substrate 2 in a spatially selective manner using known lithographic processes.

Besides a chromium etching mask, it is possible in this step to also use other materials for etching masks. For example, for this purpose, materials such as TiO_2, SiO_2, suitable crystallite, Styropor globules, may be used to properly mask silicon substrate 2.

In the subsequent method step shown in Figure 5e, the V-shaped grooves are etched into silicon substrate 2. This is accomplished, for example, by dipping silicon substrate 2, together with etching mask 10, in a suitable etching solution of potassium hydroxide (KOH) and isopropanol (H_7C_3OH). Of course, other etching media may also be used for the requisite anisotropic etching process; for example, at this point, known methods, such as reactive ion etching, could also be employed. The desired V-shaped grooves are obtained during the anisotropic deep-etching process due to the different etching rates in silicon substrate 2 for the various crystal-plane orientations. Thus, the etching rate in the (100) direction is approximately 100 times greater than the etching rate in the (111) direction. In this connection, the etching process is continued until the resulting oblique edges or side surfaces have converged, i.e., until the V-shaped groove shown in Figure 4 is fully formed. The V-shaped groove structures that ultimately result in the process are discernible in the side view of Figure 5f. A plan view of a part of the material measuring standard in this process stage is shown in Figure 5g.

After etching, the etching mask 10 is removed from substrate 2. This may be done, for instance, using known using wet chemical etching processes. A section through the then

resulting structure is shown in Figure 5h.

The last method step is not needed in every case; particularly when the intention is for reflecting etching mask 10 to remain in the higher reflecting subsections 4b. In the case of a chromium etching mask, the chromium etching mask may remain, for example, in subsections 4b having high reflectivity. This is especially practical when a particularly high reflectivity of subsections 4b is optionally required. In principle, however, the reflectance of the silicon substrate surface, already mentioned above, suffices.

A particular benefit, in this context, of the above described method is that virtually no undercut-etching of the etching mask results, so that a mechanically stable graduated-scale structure is obtained. Furthermore, this method renders possible the manufacturing of especially fine graduation structures.

A scanning electron-microscopic picture of a first specific embodiment of the reflection-type graduation according to the present invention, as described at the outset, is depicted in Figure 6. In this context, the low reflecting subsections exhibit the above described V-shaped groove structure.

Figure 7 shows the scanning electron-microscopic picture of a detail of a second variant of the material measuring standard according to the present invention. Evident in Figure 7 is a portion of a low-reflecting subsection, where the deeply etched, oblique surfaces, as indicated above, are formed by a multiplicity of irregularly distributed pyramid-shaped depressions.

While the foregoing description and drawings represent the preferred embodiments of the present invention, it will be apparent to whose skilled in the art that various changes and modifications may be made therein without departing from the true spirit and scope of the present invention.

Abstract

A reflection-type graduation having a silicon substrate. The silicon substrate has first subsections formed thereon. Each of the first subsections has etched oblique surfaces. The surfaces are positioned so that light beams directed incident to the surfaces cause no retroreflection. The substrate also includes second subsections having relatively higher reflecting properties as compared to the first subsections. The first subsections and second subsections are alternatively disposed on the substrate in a first direction.

10/069086
JC13 Rec'd PCT/PTO 05 FEB 2002

[10901/36]

REFLECTION [MATERIAL MEASURE]-TYPE GRADUATION AND METHOD FOR [PRODUCING] MANUFACTURING A REFLECTION [MATERIAL MEASURE]-TYPE GRADUATION

Field of the Invention

The present invention is directed to a [reflectometer] reflection-type graduation, as well as to a method for manufacturing a [reflectometer.] reflection-type graduation.

[Optical incident-]Related Technology

Reflected-light position [-measuring devices] encoders usually include a [reflectometer] reflection-type graduation, as well as a scanning device that is movable [relatively thereto. Typically] relative to the reflection-type graduation. A light source is typically mounted at the scanning device [is a light source, which emits a bundle of light] that emits a light beam in the direction of the [reflectometer. From there, the light bundle] reflection-type graduation. From the reflection-type graduation, the light packet is reflected back toward the scanning device, where it is modulated [in dependence] —dependent upon displacement[,] —to pass through[, as the case may be, one or a plurality of] one or more graduated-scale scanning structures, and is ultimately [be] measured by [an opto-electronic detector system] a sensing array. The signals generated in this manner, and modulated in dependence upon displacement, are then further processed [via] by a downstream evaluation unit.

[Known reflectometers of such systems] Reflection-type graduations are typically made of a substrate material, upon which subsections having different optical properties are placed in alternating sequence. In the case of an incremental graduation, the array of the various subsections extends in the direction of measurement. It can be provided, for example, to produce subsections of high and low reflectivity on a glass substrate. As a substrate material, steel is also [optionally] used, on which subsections having high and low reflectivity are [likewise] formed. In this connection, the subsections of high reflectivity can be made of gold[, while in]. The steel surface is etched to have a frosted texture for the subsections of lower reflectivity, [the steel surface is etched dull,] so that the incident light [there] is

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absorbed or reflected diffusely [reflected].

A number of requirements are placed on material measuring standards of this kind. These include a greatest possible abrasion resistance, a high thermal resistance, defined thermal properties, as well as good long-term stability. However, the above-mentioned, known material measuring standards on glass and steel substrates only partially meet these requirements.

Summary of the Invention

An [The] object of the present invention is[, therefore,] to devise a [reflectometer] reflection-type graduation, as well as a method for manufacturing the same, [which will enable the requirements cited above to be optimally met.] having the greatest possible abrasion resistance, a relatively high thermal resistance, defined thermal properties, as well as relatively high long-term stability.

This objective is achieved by a reflection-type graduation having a silicon substrate. The silicon substrate has first subsections formed thereon. Each of the first subsections has etched oblique surfaces. The surfaces are positioned so that light beams directed incident to the surfaces cause no retroreflection. The substrate also includes second subsections having relatively higher reflecting properties as compared to the first subsections. The first subsections and second subsections are alternatively disposed on the substrate in a first direction [reflectometer having the features of Claim 1.

Advantageous specific embodiments of the reflectometer according to the present invention are derived from the measures specified in those claims which are dependent upon Claim 1].

The objective at hand is also achieved by a method for manufacturing a [reflectometer having the features of Claim 10.] reflection-type graduation by providing a silicon substrate; forming first subsections and second subsections that extend in a first direction on the silicon substrate, the first subsections and the second subsections having different optical reflecting properties; wherein, in the first subsections, a plurality of oblique surfaces is produced by deep etching, which are positioned such that no retroreflection of the light beams incident

thereto results.

[Advantageous specific embodiments of the method according to the present invention are derived from those claims which are dependent upon Claim 10.

It] As mentioned, it is provided in accordance with the present invention to employ a silicon substrate and to suitably form the subsections having different reflectivity thereon. Preferably, monocrystalline silicon is used. In this connection, the subsections having less reflectivity each include a plurality of oblique surfaces, which are produced by deeply etching the silicon substrate along different crystal directions [and which]. The surfaces are positioned such that no retro-reflection of light rays incident thereto results.

In one preferred specific embodiment of the present invention, the oblique surfaces are made up of V-shaped grooves, which extend in a direction [normal] perpendicular or parallel to that direction in which the subsections having different reflective properties are configured. As to the highly reflecting subsections, one may use the [subsections of the] bare silicon substrate surface[, not discussed further here; if indicated,] or it is also possible to coat these subsections with a suitable material.

[Alternatively] As an alternative to V-shaped grooves, the oblique surfaces in the subsections having low reflectivity may also be formed as deeply etched pyramid structures[; i.e., there]. There are[, accordingly,] various ways to produce the requisite oblique surfaces having the appropriate optical action. This variant is especially suited for material measuring standards having coarser graduation intervals.

A material measuring standard of this kind has a number of advantages. Cited in this connection are, first of all, the substantial resistance to abrasion, as well as the very high mechanical resistance of the surface of the material measuring standard. In addition, the preferably monocrystalline silicon substrate is structurally stable and no longer changes, i.e., no undesirable diffusion processes result. Furthermore, silicon possesses defined thermal expansion characteristics, which is especially significant for high-precision applications. Particularly beneficial is, for instance, the use of the material measuring standard according to the present invention in the semiconductor industry, since the position-measuring system in

question includes a material measuring standard which has the same thermal expansion coefficient as the semiconductor material to be processed. It should also be mentioned that, as a substrate material, silicon is [available] relatively [inexpensively] inexpensive in a defined state, i.e., in a stable quality with respect to impurities and surface quality. Also noted in this connection is the relatively [easy] high processability of this material.

The [reflectometer] reflection-type graduation according to the present invention may be used, of course, in many different position-measuring devices, i.e., in connection with the most widely varying scanning principles. It is, of course, likewise possible to use the [reflectometer] reflection-type graduation according to the present invention in linear measuring systems, as well as in rotary measuring systems or two-dimensional measuring systems[, etc]. In accordance with the present invention, the most widely varying material measuring standards are able to be produced, such as incremental graduations, code graduations, structures for reference marks, and so forth.

Brief Description of the Drawings

Further advantages of the present invention, as well as details pertaining thereto, are derived from the subsequent description of exemplary embodiments on the basis of the [enclosed drawing, whose] following figures [show]:

Figure 1 is a plan view of an exemplary embodiment of the [reflectometer] reflection-type graduation according to the present invention;

Figure 2 is an enlarged detail [from] of the reflection-type graduation of Figure 1;

Figures 3a is a [and 3b in each case,] sectional [views] view taken along line IIIa—IIIa of Figure 2;

Figure [4]3b is sectional view taken along line IIIb—IIIb of Figure 2;

Figure 4 is a sectional view of an individual V-[groove, into which a light beam is incident;] shaped groove of the reflection-type graduation shown in Fig. 3a, showing a light beam incident thereto;

[Figures 5a-5h in each case, individual method steps in the manufacturing of the reflectometer according to the present invention;] Figure 5a is a side view of a silicon substrate prior to processing for forming the reflection-type graduation of Figure 1;

[Figure 6] Figure 5b is a top view of a silicon substrate prior to processing for forming

the reflection-type graduation of Figure 1;

Figure 5c is a top view of a silicon substrate for forming the reflection-type graduation of Figure 1, with an etching mask applied on the substrate;

Figure 5d is a side view of a silicon substrate for forming the reflection-type graduation of Figure 1, with an etching mask applied on the substrate;

Figure 5e is a side view of a silicon substrate for forming the reflection-type graduation of Figure 1 being etched to form V-shaped grooves shown in Figure 3b;

Figure 5f is a side view of a silicon substrate for forming the reflection-type graduation of Figure 1 having been etched to form V-shaped grooves shown in Figure 3b;

Figure 5g is a plan view of a silicon substrate for forming the reflection-type graduation of Figure 1 having been etched to form V-shaped grooves shown in Figure 3b;

Figure 5h is a side view of a silicon substrate for forming the reflection-type graduation of Figure 1, after the etching mask has been removed from the substrate;

Figure 6 is a scanning electron-[microscopic picture] microscope image of a part of the [reflectometer] reflection-type graduation of the present invention in accordance with the first exemplary embodiment; and [elucidated above;]

Figure 7 is a scanning electron-[microscopic picture] microscope image of a part of a [reflectometer] reflection-type graduation of the present invention in accordance with a second exemplary embodiment.

Detailed Description

Figure 1 is a plan view of a first exemplary embodiment of the [reflectometer] reflection-type graduation in accordance with the present invention [which] that may be employed, for example, in a position-measuring device used for measuring linear displacements between two objects which are movable relatively to one another.

[Illustrated reflectometer] For this exemplary embodiment, reflection-type graduation 1 is essentially composed of an oblong silicon substrate 2 [which] that extends in measuring direction x and on which an incremental [scale-division] graduation track 3 is arranged [for this exemplary embodiment]. Incremental [scale-division] graduation track 3, in turn, is made up of first and second rectangular subsections 4a, 4b, which exhibit different optical reflecting properties for light incident thereto. Reference numeral 4a denotes the subsections of lower reflectivity; reference numeral 4b[, on the other hand,] denotes the subsections of

high reflectivity. Subsections 4a, 4b[, 4a] having low and high [and low] reflectivity are arranged in alternating sequence in a first direction x, which also corresponds to the measuring direction along which a relative displacement would be measured in a corresponding position-measuring device. Various subsections 4a, 4b are identically constructed with respect to their geometric dimensions. In first direction x, they have a width b; [normally] perpendicular thereto, in second direction y, they extend over length l, which, in this example, also corresponds to the width of incremental [scale-division] graduation track 3.

In this specific embodiment, subsections 4b, designed to reflect incident light bundles, are formed [by] on the surface of silicon substrate 2. In this instance, monocrystalline silicon substrate material having crystal orientation 100 [having been] is selected. At a wavelength λ = 860 nm, this material has a reflectance of about 32%, thereby ensuring sufficient quality of the generated sampled signals for a [reflectometer] reflection-type graduation.

A detailed description of subsections 4a having low reflectivity in accordance with the present invention is provided with reference to subsequent Figures 2 - 4. Figure 2 illustrates the detail marked in Figure 1 of [reflectometer] reflection-type graduation 1, in an enlarged representation. The two Figures 3a and 3b portray sectional views of the cut-away portion in Figure 2 through the indicated lines of intersection [AB] IIIa—IIIa and [CD] IIIb—IIIb, respectively.

[At this point, in] In the first specific embodiment, the present invention provides each of subsections 4a having low reflectivity with a plurality of oblique surfaces formed as V-shaped grooves 5.1 -5.10, 6.1 - 6.4, which are positioned in a second direction, [normally] perpendicular or in parallel to a first direction x. In the illustrated exemplary embodiment, the second direction corresponds to the y-direction. In Figure 3b, a longitudinal section through a subsection 4a along line of intersection [CD] IIIb—IIIb is shown, which makes the arrangement of the multiplicity of V-shaped grooves 5.1 - 5.10 [clearly] discernible.

As is likewise indicated in Figure 2, the (011) direction of silicon substrate 2 coincides with the x-direction; the (0-11) direction of silicon substrate 2 coincides with the y-direction, while the z-direction corresponds to the (100) direction.

A detailed view of single V-shaped groove 5.1 from Figure 3a is shown by Figure 4, once again in an enlarged representation; in particular the optical action of oblique surfaces, i.e., of V-shaped grooves on an incident light beam is [elucidated] shown here[, in particular].

As is discernible in Figure 4, [the] two [lateral surfaces 5.1a, 5.1b, i.e., the two oblique] surfaces 5.1a, 5.1b form an angle $\alpha \approx 72°$ with one another; angles β_a, β_b of the two lateral surfaces 5.1a, 5.1b formed with plane E amounting accordingly to $\beta_a = \beta_b \approx 54°$. Given such a geometrical dimensional design of V-shaped groove 5.1, a light beam L coming from direction of incidence IN is reflected in the illustrated manner twice off of side surfaces 5.1a, 5.1b and ultimately leaves V-shaped groove 5.1 in reflection direction OUT, which does not coincide with incident direction IN. Viewed from incident direction IN, when working with a multiple reflection of this kind, [V-groove 5.1, i.e.,] subsection 4a having a multiplicity of such V-shaped grooves 5.1 - 5.10 and 6.1 - 6.4[, respectively, appears to be] is less reflective than neighboring subsections 4b having plane surfaces, since no retroreflection of the light beams incident thereto results.

The oblique surfaces, i.e., V-shaped grooves disposed in accordance with the present invention in the less reflective subsections 4a are able to be manufactured [quite] advantageously due to the existing orientations of certain crystal planes of silicon substrate 2. Details pertaining to the method of the present invention are explained in the following description, on the basis of Figures 5a - 5h.

In the illustrated exemplary embodiment of [reflectometer] reflection-type graduation 1 according to the present invention in Figures 2, 3a, 3b, not only V-shaped grooves 5.1 - 5.10 are provided in the less reflecting subsections 4a, which extend in adjoining fashion in second direction y that is oriented normally to first direction x. Rather, disposed adjacently to each of longitudinal edges of subsections 4a is at least one further V-shaped groove 6.1 - 6.4, which extends nearly over entire length l of subsections 4a in the y-direction. Reference is especially made, in this connection, to the sectional view in Figure 3a, where the configuration of these additional V-shaped grooves 6.1 - 6.4 is more clearly apparent at the edges of the less reflecting subsections 4a.

This advantageously ensures that various subsections 4a, 4b are sharply delimited

from one another at the additional, lateral V-shaped grooves 6.1 - 6.4. These additional V-shaped grooves 6.1 - 6.4 are not essential, however, to the functioning of [reflectometer] reflection-type graduation 1 according to the present invention.

[While in the above exemplary embodiment, the oblique surfaces were designed in the less reflecting subsections as V-grooves, it] It is also optionally possible for the oblique surfaces to be formed as a multiplicity of pyramids or as pyramid-shaped depressions in [these] subsections 4a. These may be spaced at regular intervals or, however, also randomly distributed. This pyramid structure may be produced, just as the V-shaped grooves discussed above, by deeply etching the silicon substrate, for which, then, suitably modified etching masks are needed. For further details on a specific embodiment of this kind of material measuring standard according to the present invention, reference is additionally made here, for example, to the publication by I. Zubel, Silicon Anisotropic Etching in Alkaline Solutions II, Sensors and Actuators, A 70 (1998), pp. 260 -268, which is incorporated herein by reference.

One exemplary embodiment of the method according to the present invention for manufacturing a [reflectometer] reflection-type graduation is elucidated in the following on the basis of Figures 5a - 5h. Here, a method is described which is suited for manufacturing a [reflectometer] reflection-type graduation in accordance with the above described exemplary embodiment and in which the oblique surfaces are formed, accordingly, as V-shaped grooves. Such an embodiment in accordance with the present invention permits, in particular, the implementation of very fine graduation intervals.

With respect to a suitable method for manufacturing the mentioned structure having deeply etched, pyramid-shaped depressions, which are especially suited, in turn, for coarser graduation intervals, reference is [merely] again made to the above-mentioned publication.

The starting point for the method described in the following is silicon substrate 2 described in Figures 5a and 5b, in which the (011) direction coincides with the x-direction, and the (0-11) direction with the y-direction. This orientation of silicon substrate 2 ensures that the desired, straight edges are obtained.

In a first method step, silicon substrate 2 is provided with an etching mask 10, which, in this example, is composed of a chromium coating. The two views of Figures 5c and 5d show silicon substrate 2 having an applied etching mask 10. The nearly ladder-shaped etching mask 10 is applied here, on the one hand, in subsections 4b having the desired high reflectivity; on the other hand, etching mask 10 is also applied in the regions of low-reflecting subsections 4a, which are located between the V-shaped grooves to be produced, as well as in laterally bordering regions. In this connection, reference is made, in particular, to Figure 5d, which illustrates the regions of substrate material 2 covered by etching mask 10. Accordingly, merely those regions in which the V-shaped grooves are to be formed remain [not covered] uncovered by etching mask 10 on silicon substrate 2. Etching mask 10 is applied to the desired regions of silicon substrate 2 in a spatially selective manner using known lithographic processes.

Besides a chromium etching mask, it is[, of course,] possible in this [method] step to also use other materials for etching masks. For example, for this purpose, materials[,] such as TiO_2, SiO_2, suitable crystallite, Styropor globules, [etc.,] may be used to properly mask silicon substrate 2.

In the subsequent method step [-]shown in Figure 5e[-], the V-shaped grooves are etched into silicon substrate 2[, for which purpose]. This is accomplished, for example, by dipping silicon substrate 2, together with etching mask 10, [is dipped] in a suitable etching solution of potassium hydroxide (KOH) and isopropanol (H_7C_3OH). Of course, other etching media may also be used for the requisite anisotropic etching process; for example, at this point, known methods, such as reactive ion etching, [etc.,] could also be employed. The desired V-shaped grooves are obtained during the anisotropic deep-etching process due to the different etching rates in silicon substrate 2 for the various crystal-plane orientations. Thus, the etching rate in the (100) direction is approximately 100 times greater than the etching rate in the (111) direction. In this connection, the etching process is continued until the resulting oblique edges or side surfaces have converged, i.e., until the V-shaped groove [described] shown in Figure 4 is fully formed. The V-shaped groove structures [which] that ultimately result in the process are discernible in the side view of Figure 5f. A plan view of a part of the material measuring standard in this process stage is shown in Figure 5g.

[Finally, all that is still removed is merely] After etching, the etching mask 10 is removed from substrate 2. This may be done, for instance, using known using wet chemical etching processes. A section through the then resulting structure is shown in Figure 5h.

The last method step is not needed in every case; particularly when the intention is for reflecting etching mask 10 to remain in the higher reflecting subsections 4b. In the case of a chromium etching mask, the chromium etching mask may remain, for example, in subsections 4b having high reflectivity. This is especially practical when a particularly high reflectivity of subsections 4b is optionally required. In principle, however, the reflectance of the silicon substrate surface, already mentioned above, suffices.

A particular benefit, in this context, of the above described method is that virtually no undercut-etching of the etching mask results, so that a mechanically stable graduated-scale structure is obtained. Furthermore, this method renders possible the manufacturing of especially fine graduation structures.

A scanning electron-microscopic picture of a first specific embodiment of the [reflectometer] reflection-type graduation according to the present invention, as described at the outset, is depicted in Figure 6. In this context, the low reflecting subsections exhibit the above described V-shaped groove structure.

Figure 7 shows the scanning electron-microscopic picture of a detail of a second variant of the material measuring standard according to the present invention. Evident in Figure 7 is a portion of a low-reflecting subsection, where the deeply etched, oblique surfaces, as indicated above, are formed by a multiplicity of irregularly distributed pyramid-shaped depressions.

[It goes without saying that the above description merely elucidates possible exemplary] While the foregoing description and drawings represent the preferred embodiments[, i.e., within the scope] of the present invention, [variations thereof are also conceivable] it will be apparent to whose skilled in the art that various changes and modifications may be made therein without departing from the true spirit and scope of the present invention.

Abstract

A reflection-type graduation having a silicon substrate. The silicon substrate has first subsections formed thereon. Each of the first subsections has etched oblique surfaces. The surfaces are positioned so that light beams directed incident to the surfaces cause no retroreflection. The substrate also includes second subsections having relatively higher reflecting properties as compared to the first subsections. The first subsections and second subsections are alternatively disposed on the substrate in a first direction.

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JC13 Rec'd PCT/PTO 05 FEB 2002

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REFLECTION MATERIAL MEASURE AND METHOD FOR PRODUCING A REFLECTION MATERIAL MEASURE

The present invention is directed to a reflectometer, as well as to a method for manufacturing a reflectometer.

Optical incident-light position-measuring devices usually include a reflectometer, as well as a scanning device that is movable relatively thereto. Typically mounted at the scanning device is a light source, which emits a bundle of light in the direction of the reflectometer. From there, the light bundle is reflected back toward the scanning device, where it is modulated in dependence upon displacement, to pass through, as the case may be, one or a plurality of graduated-scale scanning structures, and ultimately be measured by an opto-electronic detector system. The signals generated in this manner and modulated in dependence upon displacement, are then further processed via a downstream evaluation unit.

Known reflectometers of such systems are typically made of a substrate material, upon which subsections having different optical properties are placed in alternating sequence. In the case of an incremental graduation, the array of the various subsections extends in the direction of measurement. It can be provided, for example, to produce subsections of high and low reflectivity on a glass substrate. As a substrate material, steel is also optionally used, on which subsections having high and low reflectivity are likewise formed. In this connection, the subsections of high reflectivity can be made of gold, while in the subsections of lower reflectivity, the steel surface is etched dull, so that the incident light there is absorbed or diffusely reflected.

A number of requirements are placed on material measuring

standards of this kind. These include a greatest possible abrasion resistance, a high thermal resistance, defined thermal properties, as well as good long-term stability. However, the above-mentioned, known material measuring standards on glass and steel substrates only partially meet these requirements.

The object of the present invention is, therefore, to devise a reflectometer, as well as a method for manufacturing the same, which will enable the requirements cited above to be optimally met.

This objective is achieved by a reflectometer having the features of Claim 1.

Advantageous specific embodiments of the reflectometer according to the present invention are derived from the measures specified in those claims which are dependent upon Claim 1.

The objective at hand is also achieved by a method for manufacturing a reflectometer having the features of Claim 10.

Advantageous specific embodiments of the method according to the present invention are derived from those claims which are dependent upon Claim 10.

It is provided in accordance with the present invention to employ a silicon substrate and to suitably form the subsections having different reflectivity thereon. Preferably, monocrystalline silicon is used. In this connection, the subsections having less reflectivity each include a plurality of oblique surfaces, which are produced by deeply etching the silicon substrate along different crystal directions and which are positioned such that no retro-reflection of light rays incident thereto results.

In one preferred specific embodiment of the present invention, the oblique surfaces are made up of V-grooves, which extend in a direction normal or parallel to that direction in which the subsections having different reflective properties are configured. As the highly reflecting subsections, one may use the subsections of the silicon substrate surface, not discussed further here; if indicated, it is also possible to coat these subsections with a suitable material.

Alternatively, the oblique surfaces in the subsections having low reflectivity may also be formed as deeply etched pyramid structures; i.e., there are, accordingly, various ways to produce the requisite oblique surfaces having the appropriate optical action. This variant is especially suited for material measuring standards having coarser graduation intervals.

A material measuring standard of this kind has a number of advantages. Cited in this connection are, first of all, the substantial resistance to abrasion, as well as the very high mechanical resistance of the surface of the material measuring standard. In addition, the preferably monocrystalline silicon substrate is structurally stable and no longer changes, i.e., no undesirable diffusion processes result. Furthermore, silicon possesses defined thermal expansion characteristics, which is especially significant for high-precision applications. Particularly beneficial is, for instance, the use of the material measuring standard according to the present invention in the semiconductor industry, since the position-measuring system in question includes a material measuring standard which has the same thermal expansion coefficient as the semiconductor material to be processed. It should also be mentioned that, as a substrate material, silicon is available relatively inexpensively in a defined state, i.e., in a stable quality with respect to impurities and surface quality. Also noted in this connection is the relatively easy processability of this material.

The reflectometer according to the present invention may be used, of course, in many different position-measuring devices, i.e., in connection with the most widely varying scanning principles. It is, of course, likewise possible to use the reflectometer according to the present invention in linear measuring systems, as well as in rotary measuring systems or two-dimensional measuring systems, etc. In accordance with the present invention, the most widely varying material measuring standards are able to be produced, such as incremental graduations, code graduations, structures for reference marks, and so forth.

Further advantages of the present invention, as well as details pertaining thereto, are derived from the subsequent description of exemplary embodiments on the basis of the enclosed drawing, whose figures show:

Figure 1	a plan view of an exemplary embodiment of the reflectometer according to the present invention;
Figure 2	an enlarged detail from Figure 1;
Figures 3a and 3b	in each case, sectional views of Figure 2;
Figure 4	a sectional view of an individual V-groove, into which a light beam is incident;
Figures 5a-5h	in each case, individual method steps in the manufacturing of the reflectometer according to the present invention;
Figure 6	a scanning electron-microscopic picture of a part of the reflectometer of the present invention in accordance with the first exemplary embodiment elucidated above;

Figure 7 a scanning electron-microscopic picture of a part of a reflectometer of the present invention in accordance with a second exemplary embodiment.

Figure 1 is a plan view of a first exemplary embodiment of the reflectometer in accordance with the present invention which may be employed, for example, in a position-measuring device used for measuring linear displacements between two objects which are movable relatively to one another.

Illustrated reflectometer 1 is essentially composed of an oblong silicon substrate 2 which extends in measuring direction x and on which an incremental scale-division track 3 is arranged for this exemplary embodiment. Incremental scale-division track 3, in turn, is made up of first and second rectangular subsections 4a, 4b, which exhibit different optical reflecting properties for light incident thereto. Reference numeral 4a denotes the subsections of lower reflectivity; reference numeral 4b, on the other hand, the subsections of high reflectivity. Subsections 4b, 4a having high and low reflectivity are arranged in alternating sequence in a first direction x, which also corresponds to the measuring direction along which a relative displacement would be measured in a corresponding position-measuring device. Various subsections 4a, 4b are identically constructed with respect to their geometric dimensions. In first direction x, they have a width b; normally thereto, in second direction y, they extend over length l, which, in this example, also corresponds to the width of incremental scale-division track 3.

In this specific embodiment, subsections 4b, designed to reflect incident light bundles, are formed by the surface of silicon substrate 2, monocrystalline silicon substrate material having crystal orientation 100 having been selected. At a wavelength λ = 860 nm, this material has a reflectance of

about 32%, thereby ensuring sufficient quality of the generated sampled signals for a reflectometer.

A detailed description of subsections 4a having low reflectivity in accordance with the present invention is provided with reference to subsequent Figures 2 - 4. Figure 2 illustrates the detail marked in Figure 1 of reflectometer 1, in an enlarged representation. The two Figures 3a and 3b portray sectional views of the cut-away portion in Figure 2 through the indicated lines of intersection AB and CD, respectively.

At this point, in the first specific embodiment, the present invention provides each of subsections 4a having low reflectivity with a plurality of oblique surfaces formed as V-grooves 5.1 - 5.10, 6.1 - 6.4, which are positioned in a second direction, normally or in parallel to a first direction x. In the illustrated exemplary embodiment, the second direction corresponds to the y-direction. In Figure 3b, a longitudinal section through a subsection 4a along line of intersection CD is shown, which makes the arrangement of the multiplicity of V-grooves 5.1 - 5.10 clearly discernible.

As is likewise indicated in Figure 2, the (011) direction of silicon substrate 2 coincides with the x-direction; the (0-11) direction of silicon substrate 2 coincides with the y-direction, while the z-direction corresponds to the (100) direction.

A detailed view of single V-groove 5.1 from Figure 3a is shown by Figure 4, once again in an enlarged representation; the optical action of oblique surfaces, i.e., of V-grooves on an incident light beam is elucidated here, in particular.

As is discernible in Figure 4, the two lateral surfaces 5.1a, 5.1b, i.e., the two oblique surfaces 5.1a, 5.1b form an angle $\alpha \approx 72°$ with one another; angles β_a, β_b of the two lateral

surfaces 5.1a, 5.1b formed with plane E amounting accordingly to $\beta_a = \beta_b \approx 54°$. Given such a geometrical dimensional design of V-groove 5.1, a light beam L coming from direction of incidence IN is reflected in the illustrated manner twice off of side surfaces 5.1a, 5.1b and ultimately leaves V-groove 5.1 in reflection direction OUT, which does not coincide with incident direction IN. Viewed from incident direction IN, when working with a multiple reflection of this kind, V-groove 5.1, i.e., subsection 4a having a multiplicity of such V-grooves 5.1 - 5.10 and 6.1 - 6.4, respectively, appears to be less reflective than neighboring subsections 4b having plane surfaces, since no retroreflection of the light beams incident thereto results.

The oblique surfaces, i.e., V-grooves disposed in accordance with the present invention in the less reflective subsections 4a are able to be manufactured quite advantageously due to the existing orientations of certain crystal planes of silicon substrate 2. Details pertaining to the method of the present invention are explained in the following description, on the basis of Figures 5a - 5h.

In the illustrated exemplary embodiment of reflectometer 1 according to the present invention in Figures 2, 3a, 3b, not only V-grooves 5.1 - 5.10 are provided in the less reflecting subsections 4a, which extend in adjoining fashion in second direction y that is oriented normally to first direction x. Rather, disposed adjacently to each of longitudinal edges of subsections 4a is at least one further V-groove 6.1 - 6.4, which extends nearly over entire length l of subsections 4a in the y-direction. Reference is especially made, in this connection, to the sectional view in Figure 3a, where the configuration of these additional V-grooves 6.1 - 6.4 is more clearly apparent at the edges of the less reflecting subsections 4a.

This advantageously ensures that various subsections 4a, 4b

are sharply delimited from one another at the additional, lateral V-grooves 6.1 - 6.4. These additional V-grooves 6.1 - 6.4 are not essential, however, to the functioning of reflectometer 1 according to the present invention.

While in the above exemplary embodiment, the oblique surfaces were designed in the less reflecting subsections as V-grooves, it is also optionally possible for the oblique surfaces to be formed as a multiplicity of pyramids or as pyramid-shaped depressions in these subsections. These may be spaced at regular intervals or, however, also randomly distributed. This pyramid structure may be produced, just as the V-grooves discussed above, by deeply etching the silicon substrate, for which, then, suitably modified etching masks are needed. For further details on a specific embodiment of this kind of material measuring standard according to the present invention, reference is additionally made here, for example, to the publication by I. Zubel, Silicon Anisotropic Etching in Alkaline Solutions II, Sensors and Actuators, A 70 (1998), pp. 260 - 268.

One exemplary embodiment of the method according to the present invention for manufacturing a reflectometer is elucidated in the following on the basis of Figures 5a - 5h. Here, a method is described which is suited for manufacturing a reflectometer in accordance with the above described exemplary embodiment and in which the oblique surfaces are formed, accordingly, as V-grooves. Such an embodiment in accordance with the present invention permits, in particular, the implementation of very fine graduation intervals.

With respect to a suitable method for manufacturing the mentioned structure having deeply etched, pyramid-shaped depressions, which are especially suited, in turn, for coarser graduation intervals, reference is merely made to the above-mentioned publication.

The starting point for the method described in the following is silicon substrate 2 described in Figures 5a and 5b, in which the (011) direction coincides with the x-direction, and the (0-11) direction with the y-direction. This orientation of silicon substrate 2 ensures that the desired, straight edges are obtained.

In a first method step, silicon substrate 2 is provided with an etching mask 10, which, in this example, is composed of a chromium coating. The two views of Figures 5c and 5d show silicon substrate 2 having an applied etching mask 10. The nearly ladder-shaped etching mask 10 is applied here, on the one hand, in subsections 4b having the desired high reflectivity; on the other hand, etching mask 10 is also applied in the regions of low-reflecting subsections 4a, which are located between the V-grooves to be produced, as well as in laterally bordering regions. In this connection, reference is made, in particular, to Figure 5d, which illustrates the regions of substrate material 2 covered by etching mask 10. Accordingly, merely those regions in which the V-grooves are to be formed remain not covered by etching mask 10 on silicon substrate 2. Etching mask 10 is applied to the desired regions of silicon substrate 2 in a spatially selective manner using known lithographic processes.

Besides a chromium etching mask, it is, of course, possible in this method step to also use other materials for etching masks. For example, for this purpose, materials, such as TiO_2, SiO_2, suitable crystallite, Styropor globules, etc., may be used to properly mask silicon substrate 2.

In the subsequent method step - shown in Figure 5e - the V-grooves are etched into silicon substrate 2, for which purpose, for example, silicon substrate 2, together with etching mask 10, is dipped in a suitable etching solution of potassium hydroxide (KOH) and isopropanol (H_7C_3OH). Of course, other etching media may also be used for the requisite

anisotropic etching process; for example, at this point, known methods, such as reactive ion etching, etc., could be employed. The desired V-grooves are obtained during the anisotropic deep-etching process due to the different etching rates in silicon substrate 2 for the various crystal-plane orientations. Thus, the etching rate in the (100) direction is approximately 100 times greater than the etching rate in the (111) direction. In this connection, the etching process is continued until the resulting oblique edges or side surfaces have converged, i.e., until the V-groove described in Figure 4 is fully formed. The V-groove structures which ultimately result in the process are discernible in the side view of Figure 5f. A plan view of a part of the material measuring standard in this process stage is shown in Figure 5g.

Finally, all that is still removed is merely etching mask 10. This may be done, for instance, using known using wet chemical etching processes. A section through the then resulting structure is shown in Figure 5h.

The last method step is not needed in every case; particularly when the intention is for reflecting etching mask 10 to remain in the higher reflecting subsections 4b. In the case of a chromium etching mask, the chromium etching mask may remain, for example, in subsections 4b having high reflectivity. This is especially practical when a particularly high reflectivity of subsections 4b is optionally required. In principle, however, the reflectance of the silicon substrate surface, already mentioned above, suffices.

A particular benefit, in this context, of the above described method is that virtually no undercut-etching of the etching mask results, so that a mechanically stable graduated-scale structure is obtained. Furthermore, this method renders possible the manufacturing of especially fine graduation structures.

A scanning electron-microscopic picture of a first specific embodiment of the reflectometer according to the present invention, as described at the outset, is depicted in Figure 6. In this context, the low reflecting subsections exhibit the above described V-groove structure.

Figure 7 shows the scanning electron-microscopic picture of a detail of a second variant of the material measuring standard according to the present invention. Evident in Figure 7 is a portion of a low-reflecting subsection, where the deeply etched, oblique surfaces, as indicated above, are formed by a multiplicity of irregularly distributed pyramid-shaped depressions.

It goes without saying that the above description merely elucidates possible exemplary embodiments, i.e., within the scope of the present invention, variations thereof are also conceivable.

What is claimed is:

1. A reflectometer made up of first and second subsections (4a, 4b) having different optical reflecting properties, which extend in a first direction (x) on a silicon substrate (2), the less reflecting first subsections (4a) including a plurality of deeply etched, oblique surfaces (5.1a, 5.1b), which are positioned such that no retroreflection of the light beams incident thereto results.

2. The reflectometer as recited in Claim 1, wherein the oblique surfaces (5.1a, 5.1b) are composed of a plurality of adjacent V-grooves (5.1 - 5.10), which are disposed in a second direction which is oriented normally to the first direction.

3. The reflectometer as recited in Claim 2, wherein the V-grooves (5.1 - 5.10) are regularly spaced in the first subsections (4.a).

4. The reflectometer as recited in Claim 2, wherein the oblique surfaces (5.1a, 5.1b) of a V-groove (5.1 - 5.10) are each oriented at an angle of (α) of approximately 72° to one another.

5. The reflectometer as recited in Claim 1, wherein, as silicon substrate material (2), monocrystalline (100) silicon is used, and the first direction (x) corresponds to the (011) direction of the monocrystalline (100) silicon.

6. The reflectometer as recited in Claim 1, wherein the width (b) of the first subsections (4.a) and the width (b) of the second subsections (4b) are selected to be identical in the first direction (x).

7. The reflectometer as recited in Claim 2, wherein, disposed at the edges of the first, non-reflecting sections (4a) is likewise at least one V-groove (6.1 - 6.4), which extends in the second direction (y) nearly over the entire length (l) of the first subsections (4a).

8. The reflectometer as recited in Claim 1, wherein a coating of highly reflective material is applied to the second, more heavily reflecting subsections (4b).

9. The reflectometer as recited in Claim 1, wherein the oblique surfaces are formed as pyramid-shaped depressions.

10. A method for manufacturing a reflectometer made up of first and second subsections (4a, 4b) having different optical reflecting properties, which extend at least in a first direction (x) on a silicon substrate (2), a plurality of oblique surfaces (5.1a, 5.1b) being produced in the less reflecting first subsections (4a) by deep etching and being positioned such that no retroreflection of the light beams incident thereto results.

11. The method as recited in Claim 10, wherein, normally to the first direction (x), a plurality of V-grooves (5.1 - 5.10) is formed in a second direction (y).

12. The method as recited in Claim 11, wherein, to form the V-grooves (5.1 - 5.10), oblique surfaces (5.1a, 5.1b) are selectively etched into the surface of the silicon substrate (2), in the region of the first subsections (4a).

13. The method as recited in Claim 12,

wherein, prior to the etching of the oblique surfaces (5.1a, 5.1b), at least the second subsections (4b) are covered with an etching mask (10) on the silicon surface.

14. The method as recited in Claim 13, wherein chromium is used as a material for the etching mask (10).

15. The method as recited in Claim 12, wherein potassium hydroxide is used in combination with isopropanol as an etching solution.

16. The method as recited in Claim 12, wherein the etching process continues until each of the V-grooves is completely formed.

17. The method as recited in Claim 13, wherein, after completion of the etching process, the etching mask is removed again.

18. The method as recited in Claim 10, wherein a plurality of pyramid-shaped depressions is etched into the silicon substrate, in the first subsections.

(12) NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT) VERÖFFENTLICHTE INTERNATIONALE ANMELDUNG

(19) Weltorganisation für geistiges Eigentum
Internationales Büro

(43) Internationales Veröffentlichungsdatum
15. Februar 2001 (15.02.2001)

PCT

(10) Internationale Veröffentlichungsnummer
WO 01/11320 A1

(51) Internationale Patentklassifikation[7]: G01D 5/347, G02B 5/00

(21) Internationales Aktenzeichen: PCT/EP00/06772

(22) Internationales Anmeldedatum: 15. Juli 2000 (15.07.2000)

(25) Einreichungssprache: Deutsch

(26) Veröffentlichungssprache: Deutsch

(30) Angaben zur Priorität:
199 37 023.0 5. August 1999 (05.08.1999) DE

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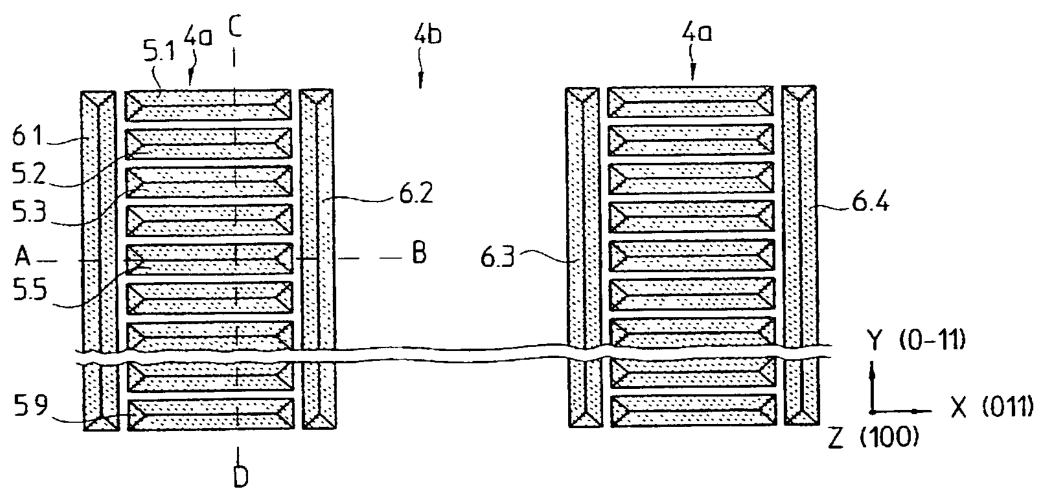
(81) Bestimmungsstaaten *(national)*: JP, US.

(84) Bestimmungsstaaten *(regional)*: europäisches Patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

[Fortsetzung auf der nächsten Seite]

(54) **Title:** REFLECTION MATERIAL MEASURE AND METHOD FOR PRODUCING A REFLECTION MATERIAL MEASURE

(54) **Bezeichnung:** REFLEXIONS-MASSVERKÖRPERUNG UND VERFAHREN ZUR HERSTELLUNG EINER RELEXIONS-MASSVERKÖRPERUNG



(57) **Abstract:** The invention relates to a reflection material measure and to a method for producing a reflection material measure. The reflection material measure consists of first and second partial regions having different optical reflection properties that extend in a first direction on a silicon substrate. The less reflective first partial regions are comprised of a plurality of inclined surfaces which are arranged in such a manner that no retroreflection of incident light beams results. The inclined surfaces are configured approximately as a plurality of adjacent V-channels, which are arranged in a second direction that is preferably perpendicular to the first direction. Alternatively, it is possible to configure a deeply etched pyramid structure in the first partial regions.

(57) **Zusammenfassung:** Es wird eine Reflexions-Massverkörperung sowie ein Verfahren zur Herstellung einer Reflexions-Massverkörperung angegeben. Diese besteht aus ersten und zweiten Teilbereichen mit unterschiedlichen optischen Reflexionseigenschaften, die sich in einer ersten Richtung auf einem

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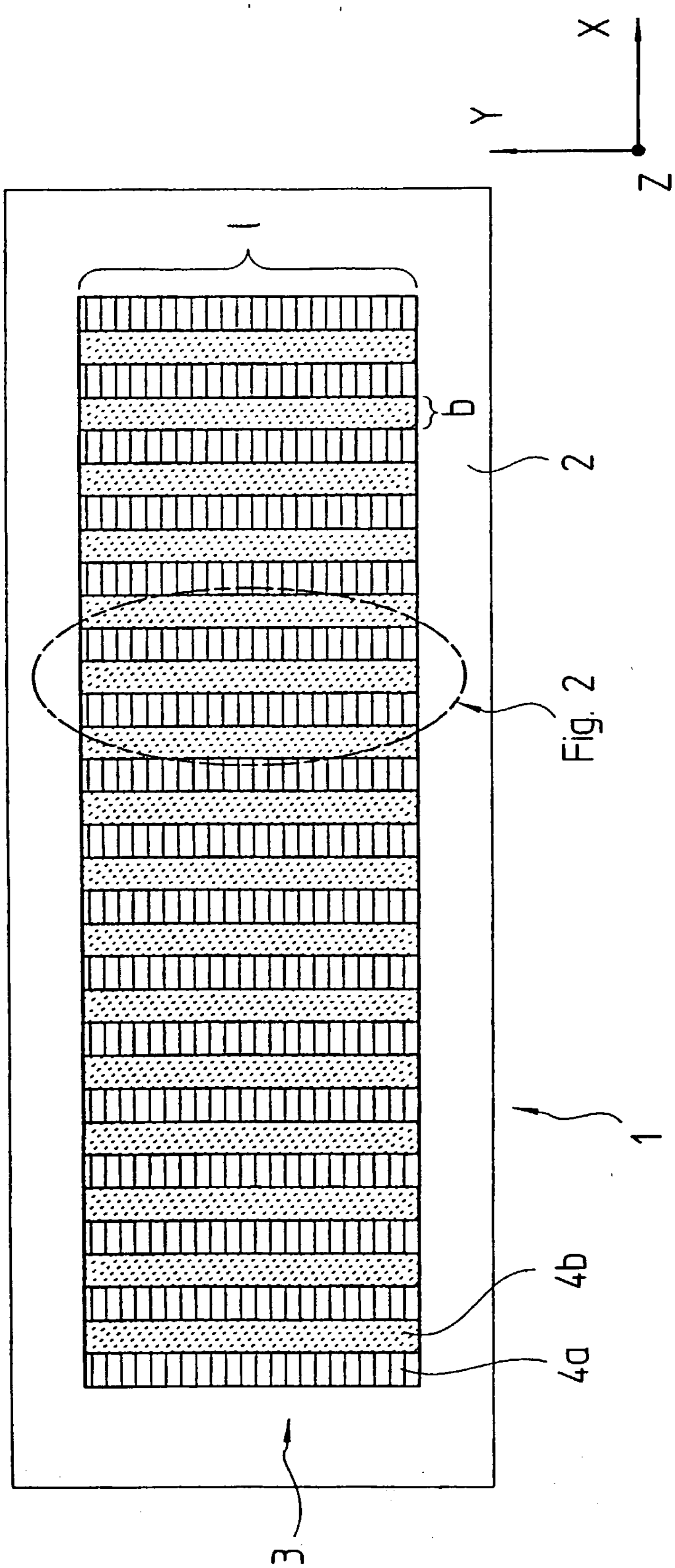


FIG. 1

FIG. 2

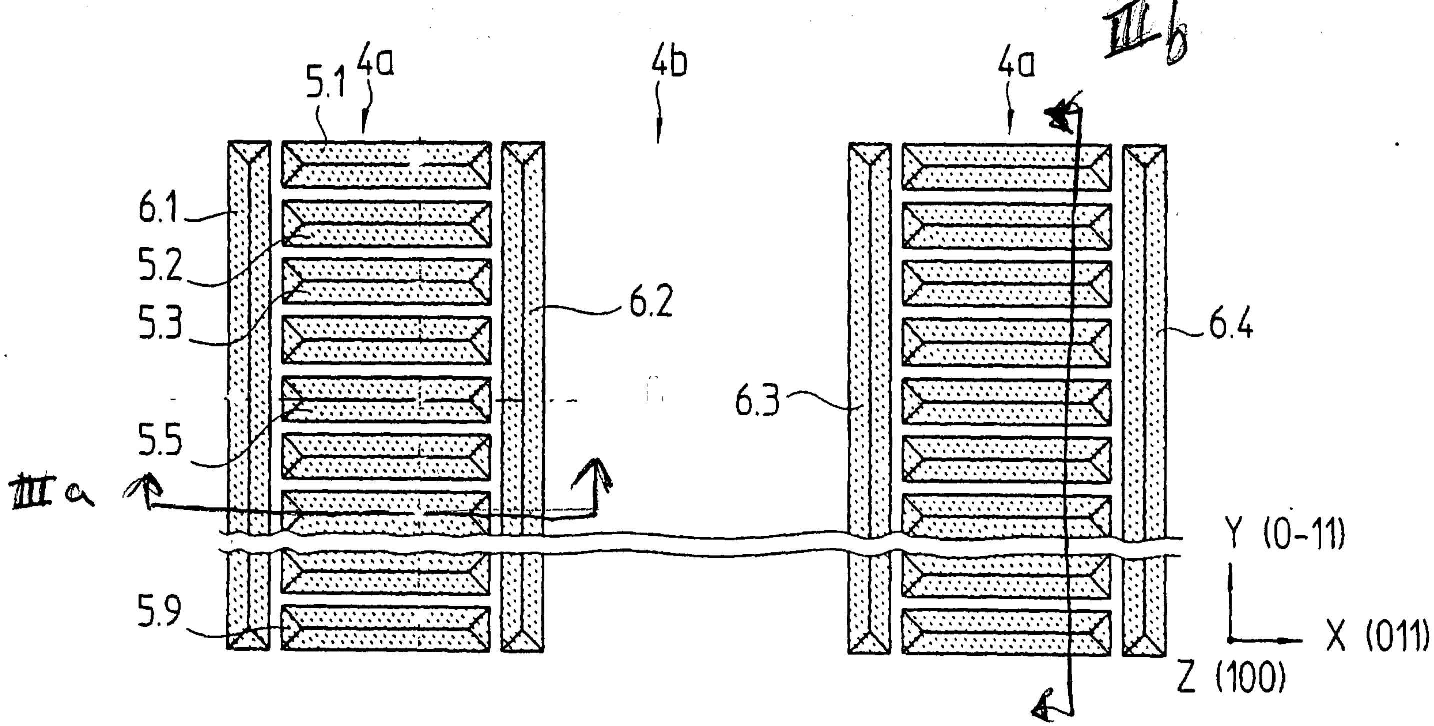


FIG. 3a

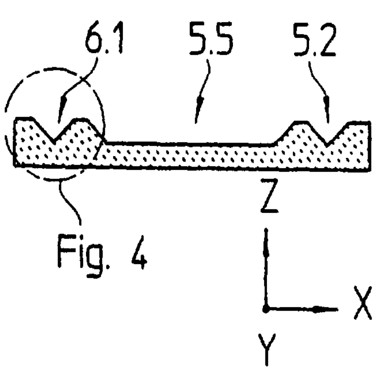


FIG. 3b

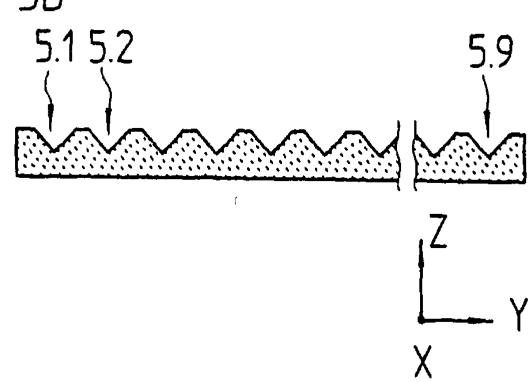


FIG. 4

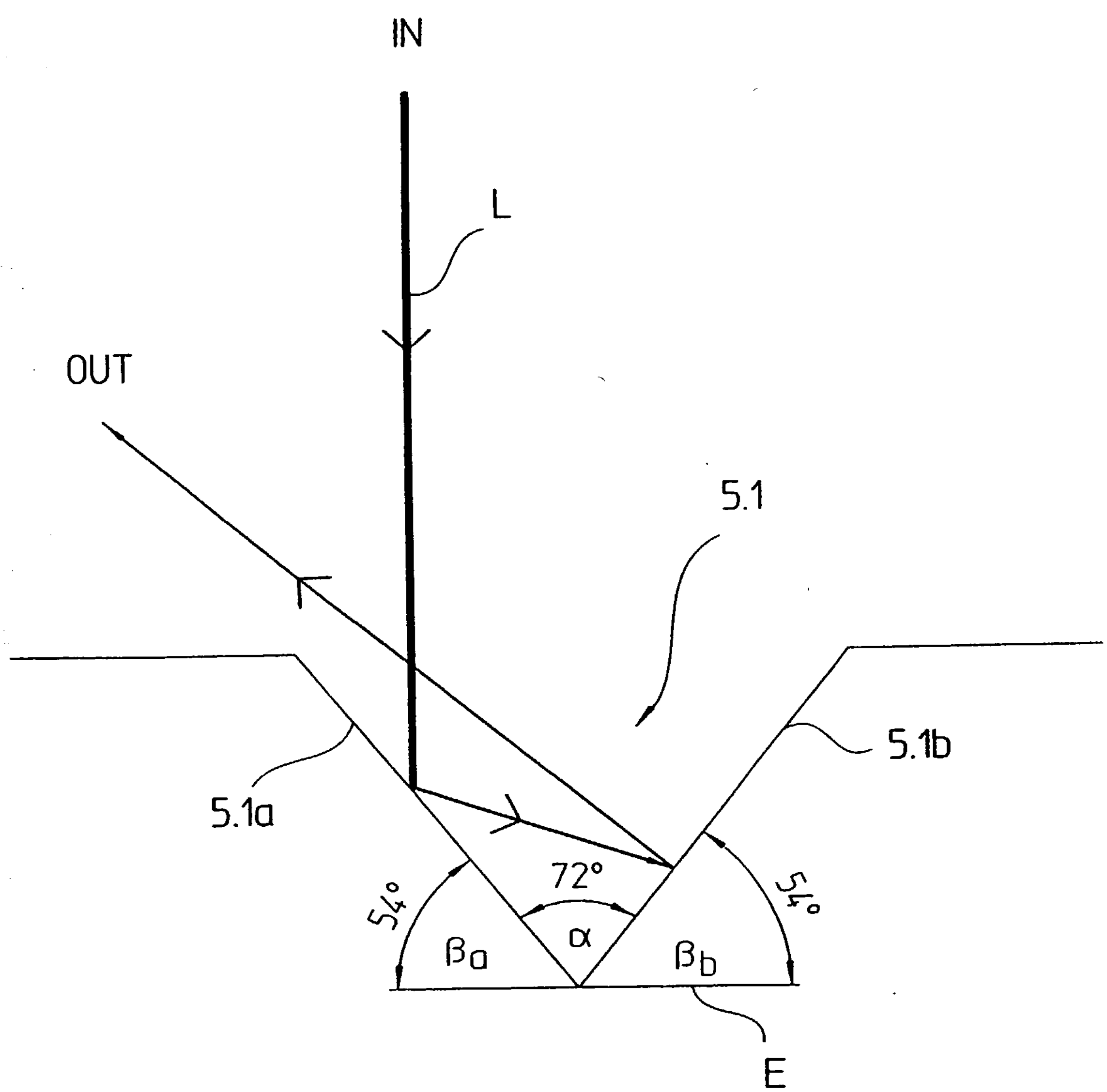


FIG. 5a

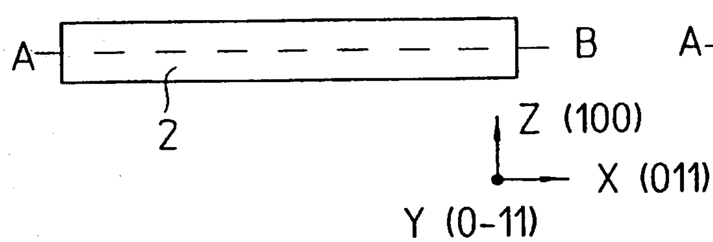


FIG. 5b

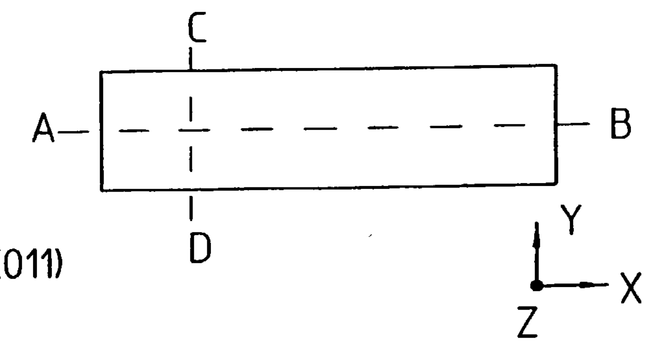


FIG. 5c

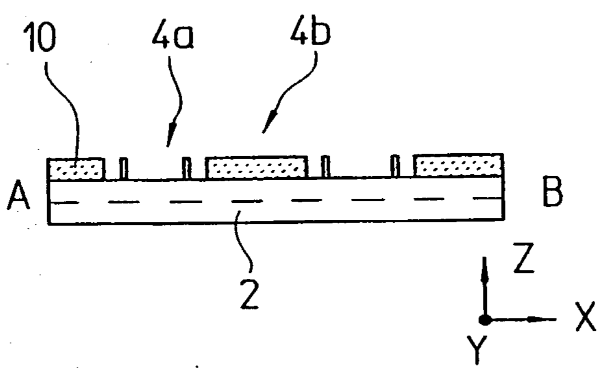


FIG. 5d

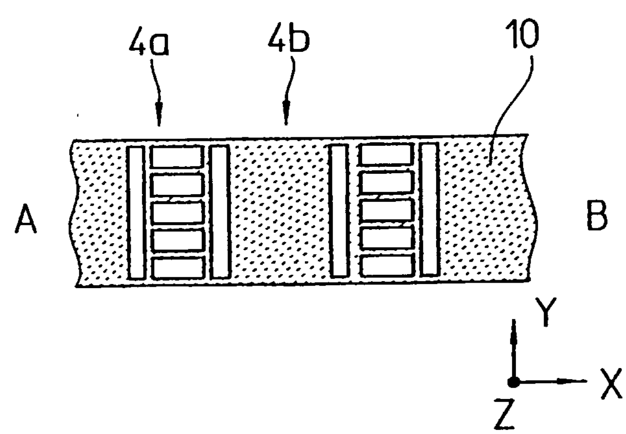


FIG. 5e

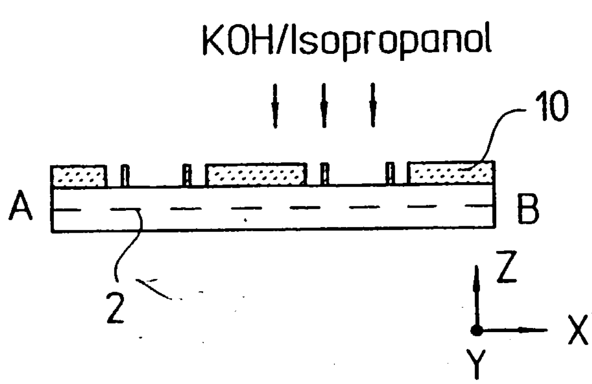


FIG. 5f

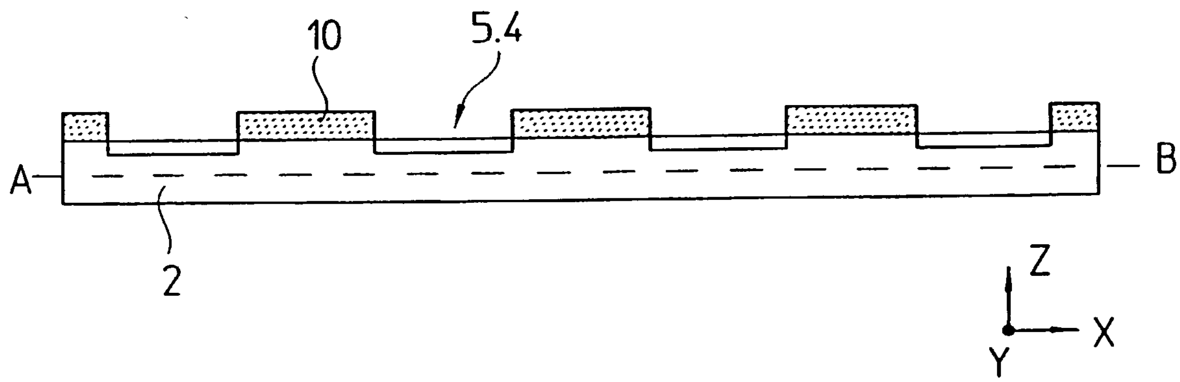


FIG. 5g

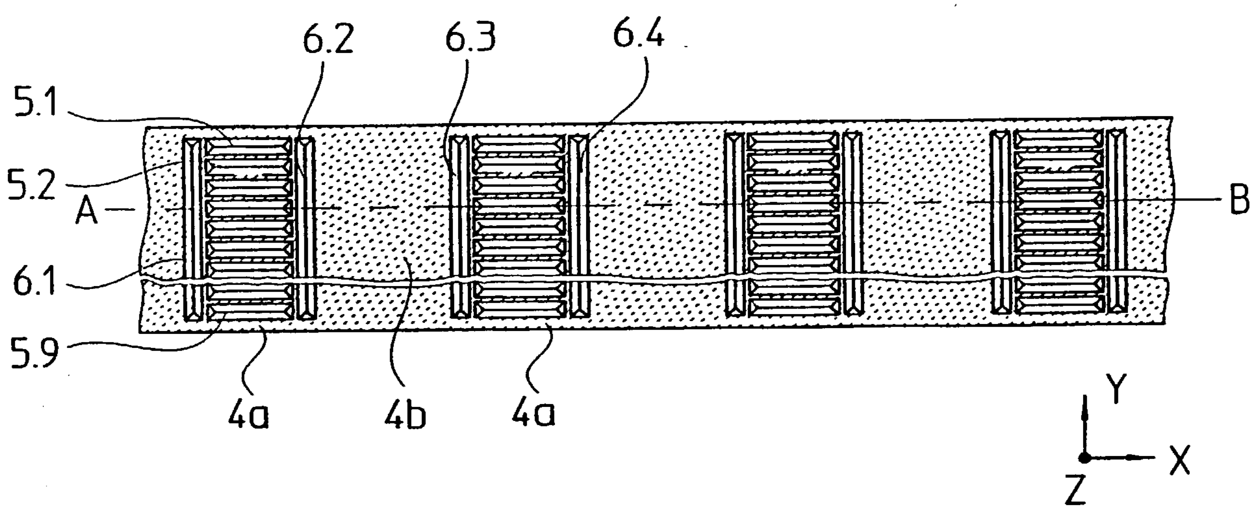


FIG. 5h

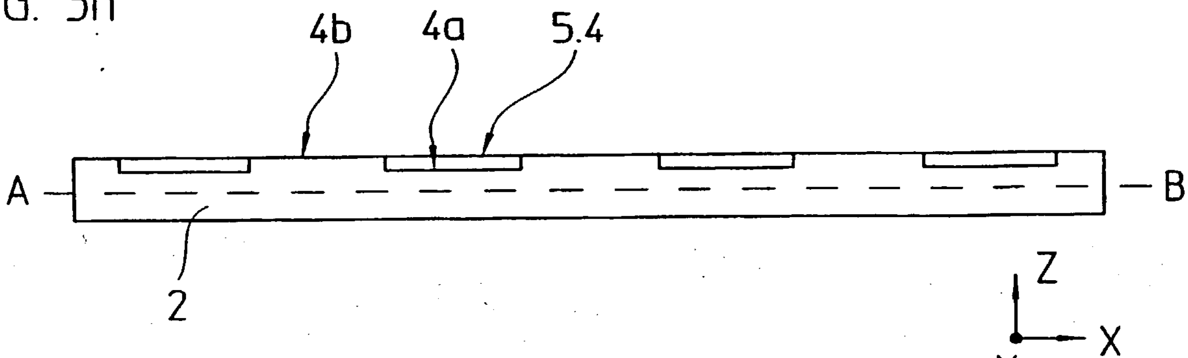


FIG. 6

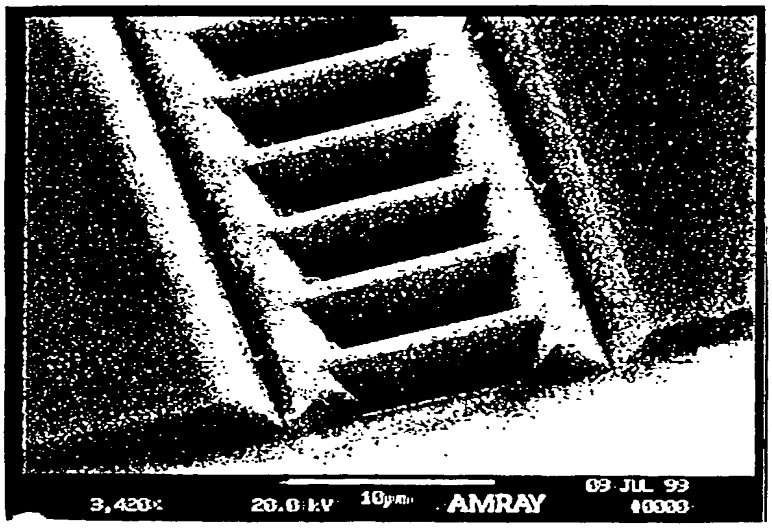
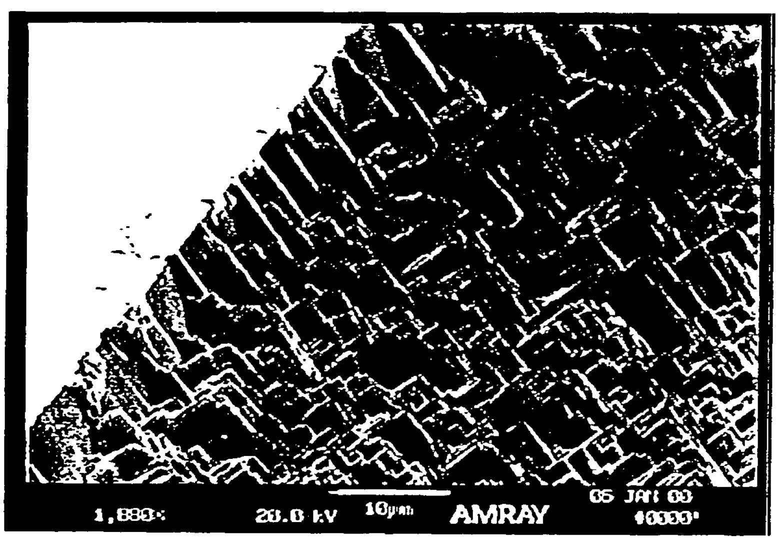


FIG. 7



[10901/36]

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **REFLECTOMETER AND METHOD FOR MANUFACTURING A REFLECTOMETER**, the specification of which was filed as U.S. Patent Application Serial No. 10/069,086 on February 5, 2002.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

Number	Country filed	Day/month/year	Priority Claimed Under 35 U.S.C. 119
199 37 023.0	Federal Republic of Germany	August 5, 1999	Yes

And I hereby appoint Richard L. Mayer (Reg. No. 22,490) and Clifford A. Ulrich (Reg. No. 42,194) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

Please address all communications regarding this application to:

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New York, New York 10004
CUSTOMER NO. 26646

26646
PATENT TRADEMARK OFFICE

Please direct all telephone calls to Richard L. Mayer at (212) 425-7200.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

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